



UNITED STATES ARMY
ENVIRONMENTAL HYGIENE
AGENCY

ABERDEEN PROVING GROUND, MD 2 10 1 O-5422

THE DEPARTMENT OF THE ARMY RADON PROGRAM

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DEPARTMENT OF THE ARMY
U.S. ARMY HEALTH PROFESSIONAL SUPPORT AGENCY
5109 LEESBURG PIKE
FALLS CHURCH, VA 22041-3258



REPLY TO
ATTENTION OF

SGPS-PSP-E (40)

19 SEP 1989

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3. The staff point of contact is LTC C. Day, Radiological Hygiene Consultant, AUTOVON 289-0132. The technical point of contact is 2LT Gary Matcek, U.S. Army Environmental Hygiene Agency, AUTOVON 584-3502.

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DEPARTMENT OF THE ARMY
U. S. ARMY ENVIRONMENTAL HYGIENE AGENCY
ABERDEEN PROVING GROUND, MARYLAND 21010-5422



June 1989

USAEHA TECHNICAL GUIDE NO. 164

THE DA RADON PROGRAM

Chapter 1

Introduction

1-1. Purpose

This technical guide--

a. Restates the responsibilities for implementing the Department of the Army's (DA) radon program as prescribed in Headquarters, Department of the Army (HQDA) letter 40-88-3.

b. Discusses the estimated physical health risks, the indoor radon standards and the measurement and mitigation procedures for the DA radon program

c. Aids in assuring the quality of laboratory analysis and field data.

1-2. References

a. HQDA letter 40-88-3, DASG-PSP(M) (1 March 1988) Office of The Adjutant General, 21 March 1988 subject: Army Radon Program (expires 21 March 1990.) (Available from Commander, U. S. Army Environmental Hygiene Agency (USAEHA), ATTN: HSHB-MD-D, Aberdeen Proving Ground, Maryland 21010-5422.)

b. EPA/625/5-86/019 Radon Reduction Techniques for Detached Houses (Available from your Environmental Protection Agency (EPA) regional office.)

c. OPA-87-009 Radon Reduction in New Construction: -An Interim Guide. (Available from your EPA regional office.)

d. EPA Pamphlet, A Citizen's Guide to Radon: What It Is and What To Do About It. (Available from your EPA regional office.)

1-3. Explanation of abbreviations and terms

Abbreviations and special terms are explained in the glossary,

1-4. Technical assistance

a. Mitigation procedures. Request technical assistance from the Director, U.S. Army Engineering and Housing Support Center (USAEHSC), ATTN: CEHSC-FU-S, Building 358, FT Belvoir, VA 22060-5516.

b. Other. Personnel living in privately owned buildings should seek information or assistance regarding the measuring of radon levels from their local health department.

c. Additional guidance in the placement of detectors. Per AR 40-5, request technical assistance by calling USAEHA, AUTOVON 584-3502 or commercial (301) 671-3502.

Chapter 2

DA Radon Program

2-1. Purpose

The DA radon program will--

a. Identify Continental United States and Outside Continental United States structures, owned and leased by the Army (including civil works) that have indoor radon levels greater than 4 picoCuries per liter of air (pCi/L).

b. Modify those structures having radon levels greater than 4 pCi/L so that the radon levels are no more than 4 pCi/L.

2-2. Responsibilities

a. The major Army command (MACOM) commanders will--

(1) Ensure that their installations initiate radon identification and mitigation programs per this technical guide.

(2) Report annually on the progress of their installations' identification and mitigation programs.

(a) Submit annual reports until the Army radon program is completed. The reports can be narrative in form but as a minimum they will include the following:

- Number of structures on the installation,**
- Total number of structures measured,**
- Radon concentrations in all buildings where they exceed 4 pCi/L (See table 2-1 for the ranges of radon concentrations),**
- Number of buildings mitigated, and**
- Highest radon level recorded for all measured structures.**

(b) Submit annual reports to the Director, USAEHSC, ATTN: CEHSC-FU-S, Building 358, FT Belvoir, VA 22060-5516, with a copy furnished to the Office of The Surgeon General (OTSG), [HQDA (SGPS-PSP), 5109 Leesburg Pike, Falls Church, VA 22041-3258].

b. The installation commanders will--

(1) Execute, document, and manage the radon measurement and mitigation efforts.

(2) Purchase radon detectors from the DA contractors.

(3) Deploy and retrieve the radon detectors.

(4) Ship the detectors back to the DA contractors.

(5) Provide annual summaries of the radon measurement and mitigation efforts through command channels to the Director, USAEHSC, ATTN: CEHSC-FU-S, Building 358, FT Belvoir, VA 22060-5516, with a copy furnished to the OTSG, [HQDA (SGPS-PSP), 5109 Leesburg Pike, Falls Church, VA 22041-3258].

(6) Notify the building's occupants of the test procedures and results, plus the needed mitigation actions.

(7) Implement a quality assurance (QA) plan.

(8) Develop an archival data base, which is compatible with the Army's systems for storing all measurement and mitigation data (see para 4-4).

(9) Complete the initial and long-term measurement phases by the 4th quarter, FY 91.

(10) Measure the radon levels in leased structures.

(11) Measure newly constructed buildings to determine the radon levels.

(12) Modify structures with radon levels greater than 4 pCi/L so that the radon levels are no more than 4 pCi/L.

c. Army medical department personnel will--

(1) Assess the health hazards of the radon exposure.

(2) Revise, if warranted by acceptable scientific evidence, the current exposure level criteria used for any remedial action. The present exposure level criteria are identified in table 2-1.

(3) Oversee the radon measurement phase of this program

(4) Monitor the progress of the installation's radon identification and mitigation efforts during scheduled radiation protection surveys.

d. The chief Army Corps of Engineers will--

(1) Develop construction criteria for the mitigation of radon in various types of new structures.

(2) Develop training strategies for personnel who will deploy radon detectors at each installation.

(3) Fund for the measuring of radon in Army owned and leased structures.

(4) Fund for the mitigation of radon when the levels are above the approved remedial action levels,

(5) Monitor installations' progress in identifying and mitigating radon levels in structures.

(6) Provide guidance in the post-mitigation, short- and long-term measurements (LTMS₄)

e. Chief of public affairs will establish the necessary supporting public affairs program

f. Installation medical personnel will provide appropriate consultative assistance.

g. The two DA contractors will provide the installation with--

(1) Alpha-track and charcoal detectors for use in pre- and post-mitigation measurements.

(2) Instructions for the deployment, emplacement, and retrieval of the detectors.

(3) Required data sheets, which document the measurements and ensure the proper handling of the detectors.

(4) A report of the results of the measurements and the required quality assurance (QA) or quality control (QC) data. The QA or QC data ensure the correctness and verifiability of the measurements.

(5) The statistical screening methodology. See appendix B for further guidance.

h. The QA contractor will--

(1) Oversee the analytical laboratory performance of the DA contractors.

(2) Audit the overall implementation of the radon assessment program

(3) Use EPA's radiation laboratory facilities to carry out the QA functions.

(4) Provide guidance in the placement and evaluation of 15 percent of the total number of detectors supplied, which will serve as blind controls, duplicates, and field blanks.

i. Director, USAEHSC will establish two separate contracts to provide all radon detection services by the 2d quarter, FY 89.

2-3. DA indoor radon standards

The DA has adopted EPA's recommended remedial action level as its indoor radon standard.

a. Remedial actions are taken if the annual average radon concentration in a structure exceeds 4 pCi/L.

b. Remedial actions are based on the highest measured radon concentration in a structure. Table 2-1 presents the timeframes in which remedial actions should be completed.

Table 2-1**Remedial action timeframes**

Radon concentration (pCi/L)	Remedial action required
Greater than 200*	Within 1 month or move the occupants
Greater than 20, but less than or equal to 200*	Within 6 months
Greater than 8, but less than or equal to 20**	Within 1-4 years.
Greater than 4, but less than or equal to 8**	Within 5 years
4 or less*	No action required

*** Determined by a 90-day screening or a 1-year measurement in the case of Priority 2 and 3 structures.**

**** Determined by a 1-year measurement. Installation personnel will not use 90-day screenings in this range as the basis for initiating mitigation.**

Chapter 3

Estimated Physical Health Risks

3-1. Background

Radon-²²² is a naturally occurring, inert, radioactive gas that is formed from the decay of uranium

a. Elevated levels of radon-²²² in some soils are due to a high concentration of uranium. Also, those soils that have been contaminated with the by-products of uranium or phosphate mining contain elevated levels. Soil composition alone is not a good indicator of a potential indoor radon problem. Increased indoor radon levels have been found in areas where uranium concentrations are relatively both low and high.

b. Radon levels vary considerably within the same geographic area. Adjacent structures can have radon levels that range from 20 to 100 pCi/L. This can be caused by several differences.

(1) Construction,

(2) Insulation,

(3) Soil composition, or

(4) Geology over which the structure was built.

c. The EPA estimates that we may expect 20 percent of our structures to exceed 4 pCi/L.

3-2. Increased levels of indoor radon

Radon-²²² has always been a component of indoor air.

a. Indoor radon concentrations have increased due to the Army's energy efficiency measures. These measures have resulted in the reduction in the exchange of the inside air with the outside air, therefore increasing the amount of indoor radon.

b. Higher radon levels have increased the radiation dose to our lungs, thus increasing the risk of lung cancer.

3-3. Health hazard from indoor radon

Radon exposure has been associated with an increased risk of developing lung cancer. Because many buildings have elevated levels of indoor radon-²²², this has become a significant health concern.

a. Radon-²²² has a radioactive half-life of 3.8 days. Almost all inhaled radon gas is also exhaled. Therefore, radon-²²² alone, does not deliver a significant fraction of the radiation dose to the lungs.

b. Radon-²²² decays into a series of radioisotopes, referred to as radon daughters, before becoming nonradioactive lead. Two of these radon daughters, polonium ²¹⁸ and polonium ²¹⁴ have short half-lives. They emit alpha radiation which is the most dangerous health hazard.

c. The radon daughters are electrically charged atoms which rapidly attach to dust particles. A variable portion of the atoms remains unattached and is known as the unattached fraction.

(1) As the attached radon daughters are inhaled, many of the dust particles are deposited along the respiratory tract airways.

(2) The unattached fraction is deposited even more readily than the dust particles.

(3) The magnitude of the unattached fraction and the differences in the particle sizes of the attached fraction are important factors in determining the amounts and sites of the deposits.

(4) The alpha radiation emitted from these deposits may cause damage to the cells of the bronchial epithelium. The resulting biological changes can ultimately lead to the development of a lung cancer.

3-4. Estimated risks

It is difficult to estimate the risk of lung cancer from radon exposure. Accurate calculations of the exact doses of radiation delivered to the cells that eventually become cancerous cannot be made. The EPA estimates that in a population exposed to an annual average radon concentration of 4 pCi/L for 70 years, lung cancer deaths could occur in 1 to 5 percent of the population. The EPA is continuing to refine this risk estimate.

a. The cumulative exposure to radon can be determined by multiplying the concentration of the radon daughters and the duration of the exposure. However, the relationship between the exposure and the actual dose of radiation absorbed by the target cells of the bronchial epithelium is complex. This relationship depends on both physical and biological factors.

(1) The physical factors that affect the relationship include the following:

- (a) Size distribution of the dust particles,
- (b) Proportion of unattached atoms, and
- (c) Proportion of radon daughters to radon-²²².

(2) The biological factors include the following:

- (a) Lung structure,
- (b) Breathing patterns,
- (c-) Proportion of particles deposited,
- (d) Mucus thickness, and
- (e) Mucociliary clearance rate.

Therefore, many critical assumptions must be made to produce dose estimates.

b. The occupational studies of underground miners represent the only available human epidemiological information that can be used to estimate the risk from exposure to radon in the indoor environment. These studies provide a relatively strong data base for developing exposure-risk relationships. However, numerous uncertainties must be addressed before extrapolating the calculated risk based on exposures in the mining environment to exposures in the indoor environment.

(1) These uncertainties include differences between miners and the general public and between their respective environments.

(2) Examples of these differences are as follows:

- (a) Gender,
- (b) Age at exposure,
- (c) Breathing patterns,
- (d) Level and duration of exposure,
- (e) Air quality,
- (f) Proportion of unattached radon daughters,

(g) Ventilation patterns, and

(h) Smoking habits.

c. The risk of lung cancer from radon exposure appears to be 10 or more times greater in smokers than in nonsmokers. This is partially because tobacco smoke:

(1) Affects the rate of mucociliary clearance and the thickness of the mucus layer in the airways, and

(2) Contains its own carcinogens.

Therefore, smoking then presents a particular concern when combined with radon exposure.

d. Researchers and committees studying the health risks of radon have used different approaches, assumptions, and analyses in their investigations. These studies have resulted in a wide range of risk estimates. Their findings, though, have clearly shown that there is a significant risk of lung cancer from long-term exposure to radon.

e. Applying the results of these studies to calculate the risk for a given individual is also complex. It must consider such variables as:

(1) Age,

(2) Sex,

(3) Age at onset of exposure,

(4) Duration of exposure,

(5) Cumulative exposure,

(6) Time since exposure, and

(7) Smoking habits.

3-5. Estimated risk comparisons

a. Table 3-1 presents a comparison of the estimated risks for lifetime exposure to radon from several different studies.

b. Table 3-2 compares the risk from radon with the risk from other activities, such as smoking and receiving chest x-rays.

Table 3-1**Lung cancer mortality due to lifetime exposure to radon**

Study	Cancer Deaths per 10⁶ Person WLM*
Environmental Protection Agency	300-700
Biological Effects of Ionizing Radiation - IV	350
United Nations Scientific Committee on the Effects of Atomic Radiation	200-450
National Council on Radiation Protection	130

***WLM = Working Level Months**

a. A measure of cumulative exposure.

b. The product of the concentration of radon daughters (measured in working levels) and the duration of exposure (quantified into blocks of 170 hours, which is approximately 1 "working month" in the occupational setting).

Table 3-2

Radon risk evaluation chart

pCi/L	WL *	Estimated number of lung cancer deaths due to radon exposure (out of 1000)	Comparable exposure levels		Comparable risk
200	1.0	440-770	1000 times average outdoor level		More than 60 times non-smoker risk
100	0.5	270-630	100 times average indoor level		4 pack-a-day smoker
40	0.2	120-380			20,000 chest x-rays per year
20	0.1	60-210	100 times average outdoor level		2 pack-a-day smoker
10	0.05	30-120	10 times average indoor level		1 pack-a-day smoker
4	0.02	13-50			5 times non-smoker risk
2	0.01	7-30	10 times average outdoor level		200 chest x-rays per year
1	0.005	3-13	Average indoor level		Non-smoker risk of dying from lung cancer
0.2	0.001	1-3	Average outdoor level		20 chest x-rays per year

* WL = Working Level

a. A measurement of the concentration of radon daughters.

b. Approximately the amount of energy emitted by the short half-life daughters in equilibrium with 100 pCi/L of radon (or, more likely, in 50 percent equilibrium with 200 pCi/L of radon).

Source: United States Environmental Protection Agency: Office of Air and Radiation, A Citizen's Guide To Radon. August 1986. OPA-86-004

Chapter 4

Measurement and Mitigation of Indoor Radon

Section I

Measurement Plan Overview

4-1. Objective

The objective of the measurement portion of the Army radon program is to identify all Army structures that have radon levels above the recommended remedial action level of 4 pCi/L. The program emphasizes finding and correcting quickly those Priority 1 structures with radon levels greater than 20 pCi/L.

4-2. Priority of structures

The Army has prioritized its structures so that the measurement and mitigation of indoor radon is cost effective.

a. Priority 1 - Day care centers, hospitals, schools, and living areas, i.e., quarters and billets.

b. Priority 2 - Areas having 24-hour operations, (e.g., operation centers and research, development, test and evaluation facilities).

c. Priority 3 - All other routinely occupied structures (e.g., offices and shops).

4-3. Phases of the measurement plan

The measurement plan has three phases. Below is a summary of those phases.

a. Initial phase -

(1) Consists of a 90-day screening measurement of all Priority 1 structures.

(2) Determines whether Priority 2 and 3 structures must be measured.

(3) Provides an early indication of those installations that will require increased resources for mitigation.

b. Long-term measurement (LTM) phase -

(1) Consists of measurements taken for 1 year.

(2) Uses the results from the initial phase as the basis for the 1-year measurements.

c. Mitigation verification measurement phase -

(1) Consists of post-mitigation, short and long-term measurements, which test the effectiveness of the employed mitigation techniques.

(2) Verifies the mitigation efforts with a short-term measurement as well as an LTM when the short-term measurements have indicated successful mitigation.

4-4. Development of an archival data base

a. This data base will--

(1) Contain all radon measurements and mitigation data obtained by installation personnel, and

(2) Be maintained throughout the entire radon reduction program

b. Some possible uses for this data base are to prepare annual summaries and to assist in notifying building occupants of the test results.

c. To obtain a sample of a data base, contact the commander, U.S. Army Armor Center and FT Knox, ATTN: ATZK-EH, FT Knox, Kentucky 40121-5000.

**Section II
Initial Phase**

4-5. Objective

The objective of the initial phase is to--

a. Perform radon measurements under worst-case conditions so that a rapid, conservative assessment of Priority 1 structures can be obtained.

b. Ensure that the actual annual average radon concentration will be below the recommended remedial levels.

4-6. Methodology

a. Place the alpha-track radon detectors in the lowest living area (LLA) of the structures because radon concentrations are highest in the lowest areas of a structure. See paragraph 4-15.

b. In the colder climates, perform the radon measurements during the heating season. In the warmer climates, perform the measurements during the cooling season.

(1) If installation personnel do not complete their initial screening during the winter heating season, they should continue with the 90-day screening into the spring months.

(2) Initial sample periods greater than 90 days are possible and are being used at some locations where a true closed-building period does not exist.

(3) Authority to deviate from the 90-day screening must come from the MACOMs.

c. Keep the detector(s) in place for 90 days.

d. For structures with an initial measurement that exceeds 20 pCi/L, do not perform LTMS. Check appendix A to locate the required mitigation procedures.

e. For structures having an initial measurement greater than 4 pCi/L, but less than or equal to 20 pCi/L, perform LTMS for a period of 1 year. Use two alpha-track detectors for these LTMS; one in the basement and one in the LLA.

Section III

Long-Term Measurement Phase

4-7. Objective

The objective of this phase is to use the results from the initial phase to make mitigation and long-term monitoring decisions for Priority 1, 2, and 3 structures. This phase is summarized below and is shown in appendix A.

4-8. Methodology

a. Obtaining actual annual average radon concentration Complete LTMs by keeping detectors in place for 1 year, under normal living conditions.

b. Applying to Priority 2 and 3 structures. Use the measurements obtained during the initial phase to determine whether Priority 2 and 3 structures should be measured,

(1) If all Priority 1 structures' results were 4 pCi/L or less, then Priority 2 and 3 structures should not be measured as long as:

(a) Sampled Priority 1 structures are a numerically, statistically significant sample of the installation's structures, and

(b) Sampled Priority 1 structures represent a geologic sampling of the construction areas of all Priority 2 and 3 structures.

- Chapter 3 discusses the effects of geology on the indoor radon concentration.

- On most installations, the Priority 1 structures are in different locations than the Priority 2 and 3 structures. If this is true, then the validity of the sampling is compromised because the geologic formations will also be different.

- The decision not to sample Priority 2 and 3 structures can only be made if all geologic formations on the installation have also been sampled.

(2) If all Priority 1 structures' results were 4 pCi/L or less, but the structures were not representative of the Priority 2 and 3 structures, then use one of the following methods.

(a) Perform LTMs on a statistically and geologically significant number of Priority 2 and 3 structures. Use the guidance given in appendix B, or

(b) Perform LTMs on all Priority 2 and 3 structures.

(3) If any of the Priority 1 structures have radon levels greater than 4 pCi/L, then perform LTMs on all Priority 2 and 3 structures.

c. Applying to Priority 1 structures. Recent data indicate that when measuring under the required initial phase conditions, radon levels will be approximately 2 to 4 times higher than the actual annual average concentration for the structure. Based on this information, take the following actions:

(1) For structures with levels greater than 4 pCi/L, but less than or equal to 20 pCi/L, use LTMS to determine the actual annual average radon concentration before beginning mitigation efforts.

(a) This is done to prevent unnecessary mitigation of the structures.

(b) Installation personnel can still mitigate, if required, within the timeframes prescribed previously in table 2-1 if the levels are still greater than 4 pCi/L.

(2) For structures with levels greater than 20 pCi/L, mitigate by using the timeframes given in table 2-1 without performing an LTM

(3) For all structures with levels of 4 pCi/L or less, perform no further action.

Section IV

Mitigation Verification Measurement Phase

4-g. Objective

The objective of this phase is to verify and document the effectiveness of the mitigation efforts.

4-10. Methodology

The methods used for post-mitigation will depend on the level of radon found in the structure.

a. For structures with greater than 20 pCi/L, use charcoal radon detectors to complete rapid, post-mitigation monitoring coupled with longer term verification measurements.

(1) Use charcoal detectors to obtain the initial verification of the mitigation within days and under worst-case conditions.

(2) Once the levels are below the established standards when using the rapid monitoring techniques, use LTMS to verify the effectiveness of the mitigation.

(3) For structures with levels greater than 200 pCi/L, the occupants may return to the structures based on the results of the rapid, post-mitigation monitoring.

b. For structures with levels less than or equal to 20 pCi/L, but greater than 8 pCi/L, use the following methods for obtaining post-mitigation measurements.

(1) Use alpha-track detectors that can provide results within 90 days or sooner under worst-case conditions.

(2) Once the levels are below the established standards, verify the mitigation's effectiveness by using LTMs.

c. For structures with levels less than or equal to 8 pCi/L, but greater than 4 pCi/L, use alpha-track detectors that provide results within 180 days. To verify the mitigation results, use 90- to 180-day measurements under worst-case conditions.

Section V Mitigation Overview

4-11. Techniques for existing structures

The smallest fissure in a building can be a significant point of entry for radon. Not only will diffusion allow radon to enter an occupied space, but producing a vacuum will enhance radon gas's entry. Certain activities (e.g., running a bathroom or kitchen vent fan or the ignition of a furnace) can produce a vacuum. There are two major categories of mitigation techniques, barrier and interception.

a. Barrier techniques aid in preventing radon's entry into a structure.

(1) Using the following materials have proven to be effective.

(a) Resilient materials to caulk all penetrations and cracks in a building's floor/slab.

(b) Waterproofing masonry paints.

(c) Certain floor covering materials.

(2) One drawback of using barrier techniques is the assurance of the continued integrity of the barrier. The following actions can break down the barrier's integrity.

(a) Continual building differential settlement.

(b) Shock and vibration.

(c) Loss of resiliency in the caulk, paint film or the floor covering mastic.

(3) When the integrity of the building's structure is good, a pressure barrier can be formed. This is done by inserting a fan in the lowest level of the building. This slightly pressurizes this level, which provides for radon exhaustion rather than radon infiltration. The effectiveness of this technique can be assessed by using the blower-door technique, which was used in heating, ventilation, and air conditioning studies.

b. Interception techniques--

(1) Provide a preferential path for radon, and

(2) Prevent its entry into the living space.

(3) For those homes with perimeter drain and sump systems, sealing and venting the sump system can reduce radon's entry. Additional benefit has resulted from the installation of an exhaust fan on the sealed sump system. This fan creates a slight vacuum in the perimeter drain system which vents the radon to the building's exterior.

(4) EPA has developed a similar technique, subslab ventilation, which is considered to be very effective. This technique takes advantage of the small space between the floor/slab of a building or basement and the compacted sand upon which the slab has been poured. To complete this technique:

(a) Make an opening in the slab, and

(b) Install an exhaust fan to eliminate the radon gas from beneath the slab.

(5) Current practices call for one opening for each 1,000 square feet of floor/slab surface area. One exhaust fan can connect two or more openings. The fans vent the radon to the building's exterior.

4-12. Techniques for new construction

The following are mitigation techniques that prevent unacceptable radon levels in new construction.

a. Minimizing entry pathways,

b. Maintaining a neutral pressure differential between indoor and outdoor environments to minimize vacuum conditions, and

c. Making provisions for radon interception outside of the building's envelope if high radon levels exist.

4-13. Mitigation costs

a. Mitigation costs for single-family dwellings that have radon levels between 4 and 20 pCi/L range between \$200 and \$2,500 per unit. These costs depend on:

- (1) The type of construction, and
- (2) The building condition.

b. Mitigation costs for the following structures are not well defined and are only now being developed.

- (1) Multiple-family dwellings,
- (2) Schools,
- (3) Hospitals, and
- (4) Other building types.

Section VI Detector Guidance

4-14. Procurement

a. Installation personnel can use the following assumptions to estimate the cost of the detectors.

(1) The cost of each detector will range between \$10 and \$15 (this price includes the analysis of the measurements).

(2) Each family unit will require one detector for the initial phase. National data indicate that 20 percent of the measured structures will fall within the 4 to 20 pCi/L range and will require two detectors for the LTMs.

(3) Priority 1, 2, and 3 structures may also require 1 detector per 2,000 square feet on each level tested for both the initial and LTMs.

(4) Further refinement of these estimates will be provided as the data becomes available.

b. Installation personnel can purchase detectors from the DA contractors.

4-15. Emplacement

The installation personnel will emplace the detectors using the specific instructions provided by the DA contractors. But, the following general guidance is provided for planning purposes.

a. Single-family structures.

(1) Place one detector in the LLA for the initial phase.

(2) If LTMs are required, place one detector in the LLA; if the LLA is a basement, place one detector in the basement and another on the first floor.

b. Multiple-family structures.

(1) Emplacement procedures are essentially the same as for single-family structures.

(2) If the LLA is a common, open area (e.g., an unpartitioned basement), then use one detector for every 2,000 square feet of area in the LLA and one detector for each apartment on the floor above the basement.

c. Office buildings and warehouses.

(1) Sampling methodologies are currently being developed and will be provided as soon as they are available.

(2) For planning purposes though, the EPA recommends placing one detector for every 2,000 square feet in the LLA.

Chapter 5
Quality Assurance and Quality Control

Section I
QA and QC Overview

5-1. Background

a. The Army will follow a QA program which--

(1) Assures that the test results generated by the radon program are accurate and precise,

(2) Assures that the test results conform with the EPA's standard-radon testing protocols, and

(3) Entails close cooperation with the EPA and the independent QA contractor.

b. The Army will also follow an internal QC plan which provides guidance in the handling and placement of alpha-track detectors. These detectors are used in the initial screening phase. Subsequent instructions will follow regarding the Army's internal QC plan for charcoal detectors.

5-2. Handling and placement of detectors

a. Installation personnel will use the handling and placement instructions provided by the DA contractors to deploy the radon detectors. Along with the detectors, the contractors will also provide data recording sheets and data summary sheets.

(1) Data recording sheets will indicate each detector's mode of deployment and placement-location. Installation personnel will not return these sheets to the DA contractors.

(2) Data summary sheets will only contain the following information.

(a) Installation's name,

(b) Detectors' serial numbers, and

(c) Dates of placement and retrieval.

b. Installations will return the data summary sheets and the exposed alpha-track detectors to the DA contractor.

C. The Army, in cooperation with the EPA, has developed the following additional QA instructions. Each alpha-track detector comes sealed in an aluminum foil. The detector's serial number is printed on the foil and on the detector. Complete the following actions for each alpha-track detector:

(1) Record the placement and retrieval dates on the detector's label in . ink,

(2) Record the placement and retrieval dates on the detector's data sheet, and

(3) At the conclusion of the monitoring period, seal the detector using the adhesive "Gold Seal."

Section II

Blind Control Samples

5-3. Objective

The objective of the blind controls is to ensure that the test results fall within acceptable accuracy limits. Three percent of the delivered detectors will become blind controls or spiked samples.

5-4. Methodology

a. The QA contractor will expose these detectors to known radon levels in an EPA radiation laboratory. Only the installations and the QA contractor will know which detectors' serial numbers represent the blind control samples.

b. Installation personnel will randomly select the blind control samples from the delivered detectors. These samples will be set aside, without opening the packages, for shipment to the QA contractor.

c. The QA contractor will return the spiked samples to the installations within the radon measurement time period. Installation personnel should complete the following measures to disguise the spiked samples as used detectors:

(1) Mix them with the rest of the detectors,

(2) Mark the spiked samples with the same ink and preferably the same handwriting as the used detectors, and

(3) Use placement and retrieval dates similar to those appearing on the used detectors.

Section III
Duplicate Samples

5-5. Objective

The objective of placing the duplicate samples is to ensure that the test results fall within acceptable precision limits.

- a. Ten percent of the delivered radon detectors will become duplicate samples.
- b. The duplicate samples are detectors that will be concurrently exposed with every tenth regularly exposed detector in an identical location.
- c. Only the installation personnel and the QA contractor will know which detectors' serial numbers represent the duplicate samples.

5-6. Methodology

At every tenth testing location, installation personnel will place two randomly selected detectors within three feet of each other. These detectors will be exposed to the same conditions for the same length of time.

- a. Select every tenth testing location using the placement sequence given on the data recording sheets.
- b. Make sure the duplicate samples do not have consecutive serial numbers.

Section IV
Field Blanks

5-7. Objective

The objective of the field blanks is to identify the background levels, which the detectors have been exposed to during handling and shipment.

- a. Two percent of the radon detectors will become the field blanks.
- b. Only the installation and the QA laboratory personnel will know which detectors' serial numbers represent the field blanks.

5-8. Methodology

a. Installation personnel will randomly select two detectors from each box to serve as the field blanks. Most boxes contain 100 detectors, some will contain fewer, but the maximum number per box will be 125 detectors.

b. The field blanks will be set aside, in their sealed aluminum foil, for the entire radon testing period. Complete the following procedures when the radon testing period is ended.

(1) Break the aluminum foil packaging of the field blanks when all detectors are collected for return shipment, and

(2) Immediately seal the detectors with the "Gold Seal" without actually placing them

c. Take the following measures to disguise the field blanks so that they will look like used detectors:

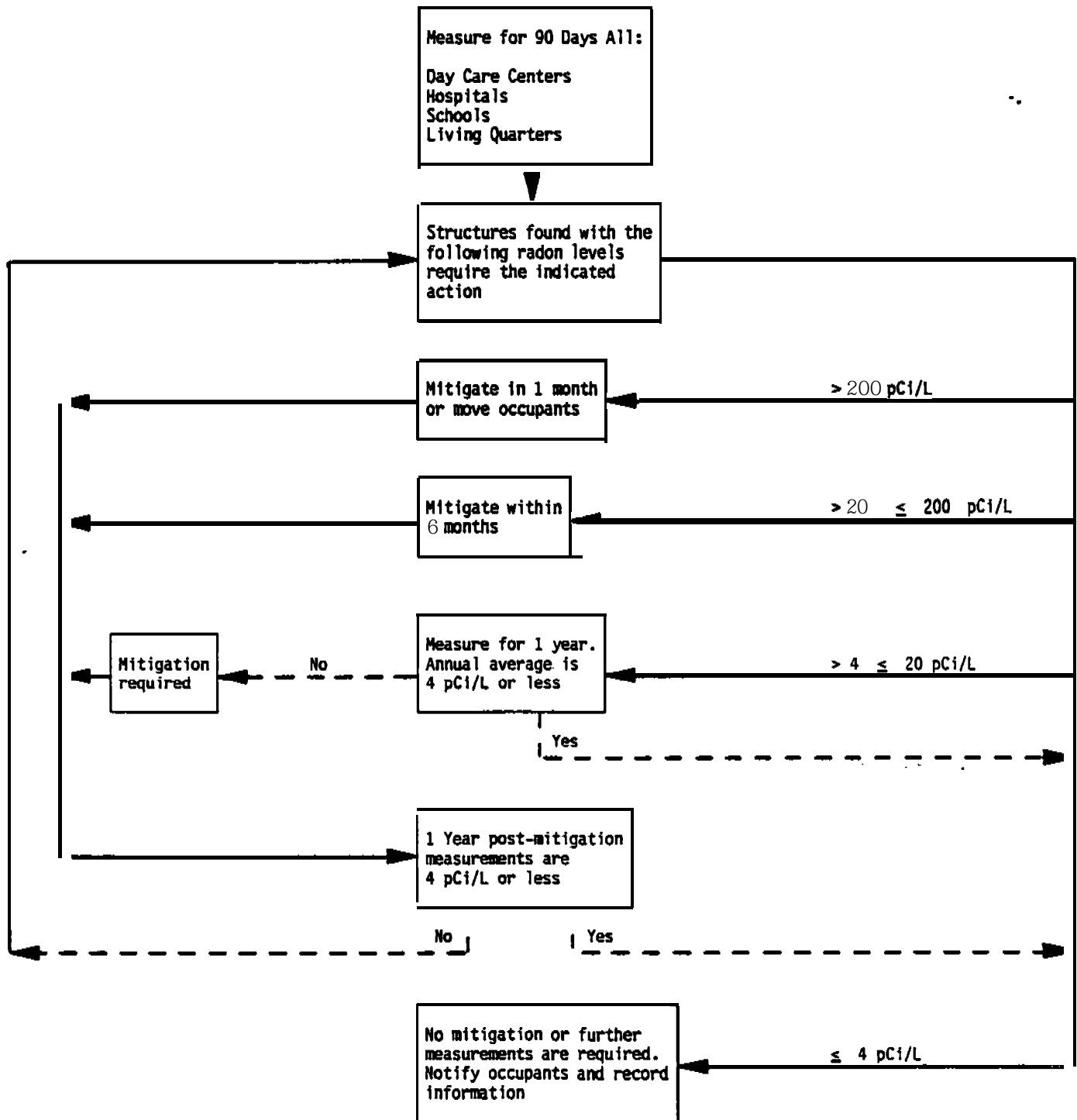
(1) Use the same ink and preferably the same handwriting to mark the field blanks with the placement and retrieval dates, and

(2) Mix the field blanks with the rest of the detectors.

This is done to ensure that the DA contractor does not know the identity of the field blanks.

Appendix A

Schematic flow chart of the actions required by Army radon program



Appendix B

Statistical Screening Methodology

B-1. Purpose

This methodology will preclude the unnecessary screening of Priority 2 and 3 structures. It is used only if the measurements obtained during the initial phase indicate that the installation does not have an indoor radon problem

B-2. Methodology

The DA contractors will provide this methodology. The chosen methodology will ensure that there is a 99.5 percent confidence in the initial measurements. Those measurements hopefully have found at least one of the structures that have radon levels in the top 5 percent of the radon level distribution on that installation.

Appendix C

Questions and Answers Regarding the Army Radon Program

Use the following questions and answers to respond to queries. Some of them (indicated by an *) came from the EPA's pamphlet "A Citizen's Guide To Radon" dated August, 1986.

***Q1. What is Radon?**

***A1. Radon is a radioactive gas which occurs in nature. You cannot see it, smell it, or taste it.**

***Q2. Where does radon come from?**

***A2. Radon comes from the natural breakdown (radioactive decay) of uranium. Radon can be found in high concentrations in soils and rocks containing uranium, granite, shale, phosphate, and pitchblende. Radon may also be found in soils contaminated with certain types of industrial wastes, such as the byproducts from uranium or phosphate mining.**

In outdoor air, radon is diluted to such low concentrations that it is usually nothing to worry about. However, once inside an enclosed space (such as a home) radon can accumulate. Indoor levels depend both on a building's construction and the concentration of radon in the underlying soil.

***Q3. How does radon affect me?**

***A3. The only known health effect associated with long-term exposure to elevated levels of radon is an increased risk of developing lung cancer. Not everyone exposed to elevated levels of radon will develop lung cancer, and the time between exposure and the onset of the disease may be many years.**

Your risk of developing lung cancer from exposure to radon depends upon the concentration of radon and the length of time you are exposed. Exposure to a slightly elevated radon level for a long time may present a greater risk of developing lung cancer than exposure to a significantly elevated level for a short time. In general, your risk increases as the level of radon and the length of exposure increase.

Q4. Should I be worried about radon?

A4. Radon is a naturally occurring radioactive gas that we have been exposed to for a long time. We've known that radon is capable of producing lung cancer if the concentration of radon is high. Indoor radon didn't become an issue until it was discovered that making homes energy efficient was causing radon levels to increase. Now that we know this, we can take steps to correct conditions in buildings to reduce the risk from radon exposure,

Q5. How serious is the threat of radon induced lung cancer?

A5. We don't know the exact risk that radon poses because there has only been one scientific study in the past. A study conducted in 1960 involved miners exposed to varying levels of radon in their work underground. There are currently studies being conducted by State and Federal agencies and when they conclude, we should have a better understanding of the risk. Meanwhile, we are using risk estimates provided by the EPA.

***Q6. How does radon cause lung cancer?**

***A6. Radon, itself, naturally breaks down and forms radioactive decay products. As you breathe, the radon decay products can become trapped in your lungs. As these decay products break down further, they release small bursts of energy which can damage lung tissue and lead to lung cancer.**

***Q7. When did radon become a problem?**

***A7. Radon has always been present in the air. Concern about elevated indoor concentrations first arose in the late 1960s when homes were found in the West that had been built with materials contaminated by waste from uranium mines. Since then, cases of high indoor radon levels resulting from industrial activities have been found in many parts of the country. We have only recently become aware, however, that houses in various parts of the U.S. may have high indoor radon levels caused by natural deposits of uranium in the soil on which they were built.**

***Q8. Does every home have a problem?**

***A8. No, most homes in this country are not likely to have a radon problem but relatively few homes do have highly elevated levels. The dilemma is that, right now, no one knows which homes have a problem and which do not.**

***Q9. How does radon get into a home?**

***A9. Radon is a gas which can move through small spaces in the soil and rock on which a house is built. Radon can seep into a home through dirt floors, cracks in concrete floors and walls, floor drains, sumps, joints, and tiny cracks or pores in hollow-block walls.**

Radon also can enter water within private wells and be released into a home when the water is used. Usually, radon is not a problem with large community water supplies, where it would likely be released into the outside air before the water reaches a home.

In some unusual situations, radon may be released from the materials used in the construction of a home. For example, this may be a problem if a house has a large stone fireplace or has a solar heating system in which heat is stored in large beds of stone. In general, however, building materials are not a major source of indoor radon.

Q10. Should I move my family out of my quarters?

A10. Families should not move out of their quarters until the indoor radon level for that structure has been determined. Buildings that have levels greater than 200 (pCi/L) picoCuries per liter of air are to be remedied within a month after the results are known. If the level cannot be lowered in that time, you will be relocated to a less hazardous living environment.

Q11. How is radon detected?

A11. Since you cannot see or smell radon, special equipment is needed to detect it. The two most popular, commercially available radon detectors are the charcoal and the alpha-track detector. The Army will be using both of these detectors.

***Q12. How can I reduce my risk from radon?**

***A12. Your risk of lung cancer from exposure to radon depends on the amount of radon entering your home and the length of time it remains in your living areas. Listed below are some actions you might take to immediately reduce your risk from radon. These actions can be done quickly and with minimum expense in most cases.**

a. Spend less time in areas with higher concentrations of radon, such as the basement.

b. Whenever practical, open all windows and turn on fans to increase the air flow into and through the house. This is especially important in the basement.

c. If your home has a crawl space beneath, keep the crawl-space vents on all sides of the house fully open all year.

Q13. Why is the Army concerned about radon?

A13. People who breathe high concentrations of radon over a period of years have an increased risk of lung cancer. The Army wants to safeguard the health of soldiers, military families, and its civilian work force. The Army radon program will identify and fix buildings where radon levels exceed recommended EPA guidelines.

914. What does the Army intend to do about radon?

A14. The Army is preparing to--

a. Survey for radon on all its installations,

b. Fix those buildings in which radon levels exceed the EPA established guideline of 4 pCi/L,

c. Resurvey all buildings where mitigation has taken place, and

d. Ensure that newly constructed buildings are within EPA guidelines for radon.

Q15. Can you give me a schedule of significant actions that will be taken?

A15. The Army began testing for radon during the Winter of 1988-89. The Army has established a contract to procure radon detection devices by the end of FY 88. Installations will be able to purchase the devices through the USAEHSC. The contractor will provide both the devices and support for laboratory analysis.

Each Installation Commander will establish a schedule for testing. Buildings will be tested according to the following priorities:

a. First: day care facilities, hospitals, schools, living quarters (BOQ/BEQ and billets).

b. Second: areas having 24-hour operations (operations centers, training and research, development, test and evaluation facilities).

c. Third: all other facilities that are routinely inhabited.

All testing will be completed by the end of FY 91.

Q16. How will the assessment be done?

A16. The Army will assess indoor radon levels by placing radon detectors at selected locations inside its buildings. The detectors will stay in place for 90 days. They will then be removed and sent to a laboratory for analysis.

The device the Army has chosen is the alpha-track detector, which consists of a small strip of plastic. Alpha particles, released when radon decays, hit the plastic strip and make microscopic tracks. These tracks become visible when the detector is immersed in an etching solution at the laboratory. The number of tracks on the strip enables technicians to calculate the average radon concentration in the building during the testing period.

There is another commonly used testing device called the charcoal canister. Though this device is less expensive than the alpha-track detector, the Army did not choose to use it for the assessment phase of the radon program mainly because it cannot be used to estimate average radon concentrations for periods longer than a week.

417. Which Army installations will be involved?

A17. The Army will survey all of its installations worldwide.

418. If excessive levels of radon are found on an installation, what is the health hazard?

A18. Any health hazard is confined strictly to the building in which an elevated radon level is found. The danger from breathing high concentrations of radon over a period of years is an increased risk of lung cancer. This increased risk depends on the levels found in the building, the length of exposure, and other factors such as smoking habits and exposure to other carcinogens. It takes years of exposure to significantly increase the risk. The Army wants to minimize the risk for soldiers, families, and civilian employees on its installations by ensuring that they do not undergo excessive radon exposure in Army facilities.

Q19. How will we learn the results of the assessment?

A19. Installation commanders will be responsible for notifying residents.

420. What will happen to families and employees in facilities that contain high levels of radon?

A20. The actions taken will depend on the radon level found in the building. Where levels over 200 pCi/L are found, such cases should be rare, the occupants may be moved to temporary housing or office space if the radon cannot be reduced to an acceptable level within a month. Occupants will be able to remain in buildings that show readings of below 200 pCi/L, because at these levels the hazard from radon exposure is not great enough to require evacuation in the period between testing and completed mitigation action.

This is consistent with EPA and Centers For Disease Control guidelines, and takes into account the risk of exposure between the time the building is sampled and the time it is mitigated. Staying in the building for this length of time is not expected to have a significant effect on the individual's overall lifetime risk of developing lung cancer.

Q21. When will the mitigation begin and how long will it take?

A21. Again, this depends on the seriousness of the radon problem found in individual buildings. Mitigation actions will be prioritized according to the radon level found in the survey. Those buildings with the highest radon levels will be mitigated first. All buildings with average annual radon levels greater than 4 pCi/L will eventually be mitigated. Those structures which do not have levels in excess of the EPA guideline level of 4 pCi/L will not require mitigation.

The Army's remedial action levels for its buildings conform with EPA guidelines, and will be implemented as follows:

a. Greater than 200 pCi/L - Begin mitigation immediately. If remedial action cannot reduce radon levels within one month, occupants will be relocated to another living or working environment while mitigation work continues.

b. Greater than 20 pCi/L, but less than or equal to 200 pCi/L - Remedial action will begin within 6 months.

c. Greater than 8 pCi/L, but less than or equal to 20 pCi/L - The building will be retested for a 12 month period. If the second reading still shows between 8 and 20 pCi/L, remedial action will be taken within 1-4 years depending on the level of the measurement.

d. Greater than 4 pCi/L, but less than or equal to 8 pCi/L - Retest the building for a 12 month period. If the second reading still shows levels in this range, take remedial action within 5 years.

All buildings which have undergone remedial actions will be remeasured to ensure radon levels do not exceed 4 pCi/L.

422. What will the Army do to fix buildings?

A22. The Army will seal cracks and openings where radon enters the building and improve ventilation so radon gas does not accumulate. A variety of measures may be taken, depending on the structure and the source of the radon. One technique is to suction the radon gas away from the building through a simple pipe, fitted with a fan. This draws the radon gas out of the subsoil before it can enter the building. Costs of mitigation will depend on the mitigation method employed, and will vary from building to building. The cost of modifying a single family housing unit usually ranges between \$200 and \$2,500.

Q23. Will mitigation eliminate future problems?

A23. Yes. The mitigation techniques that will be used have been demonstrated by the EPA to be very effective in permanently reducing radon to acceptable levels. Follow-up radon sampling will be performed in mitigated buildings to ensure that the actions have been successful.

Q24. How much will the program cost?

A24. The cost of the program will depend on how many buildings need radon mitigation. Based on findings in states that have done testing, the Army estimates that up to 20 percent of the buildings tested may need some type of mitigation action. The cost of surveying for radon will likely be \$20 to \$30 million. The cost of mitigation may be around \$120 million.

Q25. Where will the money come from?

A25. The money will come out of the installations' operations and maintenance funds.

Q26. What about leased buildings, government leased, and government rental guarantee housing?

A26. The Army plans to test all such buildings for radon. The responsibility for mitigation action will be the owners'. Because this involves landlords and lease agreements, the details of this part of the program must be negotiated.

Q27. What about new buildings?

A27. To prevent excessive radon migration in new buildings, mitigation measures will be part of all new Army construction.

Q28. What about soldiers who own or rent homes privately?

A28. Local health departments and State environmental protection agencies have radiation control programs. Contact them for assistance.

Q29. What are the EPA standards for radon? How much is considered hazardous?

A29. In its guidelines, the EPA recommends a remedial action level for radon above an annual average concentration of 4 pCi/L. What does this mean? Above this level of exposure, the EPA suggests that buildings in which people live and work for extended periods of time should be remediated. The health risk

increases as the radon level increases. At 15 pCi/L, for example, the exposure level is equivalent to smoking a pack of cigarettes a day. At around 4 pCi/L, the risk is very roughly equivalent to smoking 8 cigarettes a day.

430. How did EPA set this level?

A30. The EPA has found that it is technically feasible to lower radon levels to 4 pCi/L in nearly all cases at a reasonable cost. To achieve lower levels can be either very difficult or very expensive-or both.

Q31. What is the radon level in the surrounding community? Was this a factor in the decision to check the installation's radon level?

A31. Information from the State environmental agency's radon coordinator indicates that levels in this area have been found to be _____. (If your installation is in a geological area where radon is known to be prevalent, be prepared to address questions about the urgency for testing. Whatever the regional radon findings are, be aware that radon levels can vary greatly from building to building--not just from neighborhood to neighborhood. Since findings "next door" do not necessarily indicate the probable radon level in neighboring buildings, the Army has decided to survey all of its habitable buildings according to the priorities discussed in answer number 15 above. Remember, all Army installations are being tested.)

Glossary

Section I

Abbreviations

LLA	lowest living area
LTM	long-term measurement
MACOM	major Army command
OTSG	Office of The Surgeon General
pCi/L	picoCuries per liter of air
QA	quality assurance
QC	quality control
USAEHA	U. S. Army Environmental Hygiene Agency
USAEHSC	U. S. Army Engineering and Housing Support Center

Section II

Special Terms

Alpha radiation

Positively charged particles, which have low penetrating power and a short range.

Annual average radon concentration

Radon concentrations over a 12 month period.

Blind controls

Three percent of the delivered detectors' which ensure that the test results fall within acceptable accuracy limits,

Duplicates

Ten percent of the delivered radon detectors, which ensure that the test results fall within acceptable precision limits.

Field blanks

Two percent of the delivered radon detectors, which identify the background levels that the detectors have been exposed to during handling and shipment.

Lowest living area

The livable area closest to the underlying soil that the residents now use or could adapt for use.

picoCurie

.000000000001 Curies

Radioactive half-life

The time it takes a radioactive substance to decay to one-half of its initial activity.

Rapid monitoring techniques

Post-mitigation monitoring using charcoal detectors where you obtain measurements within days for comparative purposes.

Worst-case conditions

Ninety-day closed house measurement.

